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OBSERVATIONS ON SURFACE DISTRIBUTION OF MARINE DIATOMS BETWEEN SAN DIEGO AND SEATTLE

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In June, 1920, Dr. G. F. McEwen, while on a voyage from San Diego to Seattle and back, made a number of surface hauls of from two to five gallons of water from the decks of the passenger steamers. In connection with this work and with that of collecting water samples he secured the attention and interest of Mr. J. R. Mortensen, Second Officer of the steamer *Queen* of The Admiral Line, who volunteered to take similar collections for the use of the Scripps Institution at such times as he might be able to find. In the six months from July to December, inclusive, he was able to make a total of sixty-six collections of phytoplankton fairly well distributed as to both time and locality. The collections taken by Dr. McEwen totaled one hundred and one, and were taken at hour or half-hour intervals when it was found convenient in the two or three days actually spent at sea. In both series catches were made by the simple process of throwing a canvas bucket into the water, hauling it up and pouring the water thus secured through a filtration net of number 25 bolting silk. Most of the samples of water from which the catches were taken were small (two or three gallons), hence the catch was made with so few casts of the bucket that the ship had not made much progress during the hauling. For this reason sampling was fairly indicative of surface distribution of organisms in the immediate vicinity of the catch.

Enumeration was done by a modified Sedgwick-Rafter method. Estimates were recorded in number of specimens per liter. The records were then tabulated according to areas based on prominent localities, each area being about sixty to one hundred miles in length parallel to the coast line. Fourteen such areas were designated as indicated on the accompanying map.

Each of these fourteen areas showed at least a few diatoms in all or nearly all of the catches made by Mr. Mortensen, but in the more frequent catches made by Dr. McEwen on the single round trip there were eleven barren catches taken in the areas between Point Cabrillo and Cape Disappointment. On the other hand, some of the fifty productive catches in this area were very large.

Thirteen species of diatoms were recorded for the Mortensen series and thirty-three species for the McEwen series, the two lists being identical as far as the former goes. A few of the names are merely catch-all designations for unrecognized species or those represented by very small numbers. Most

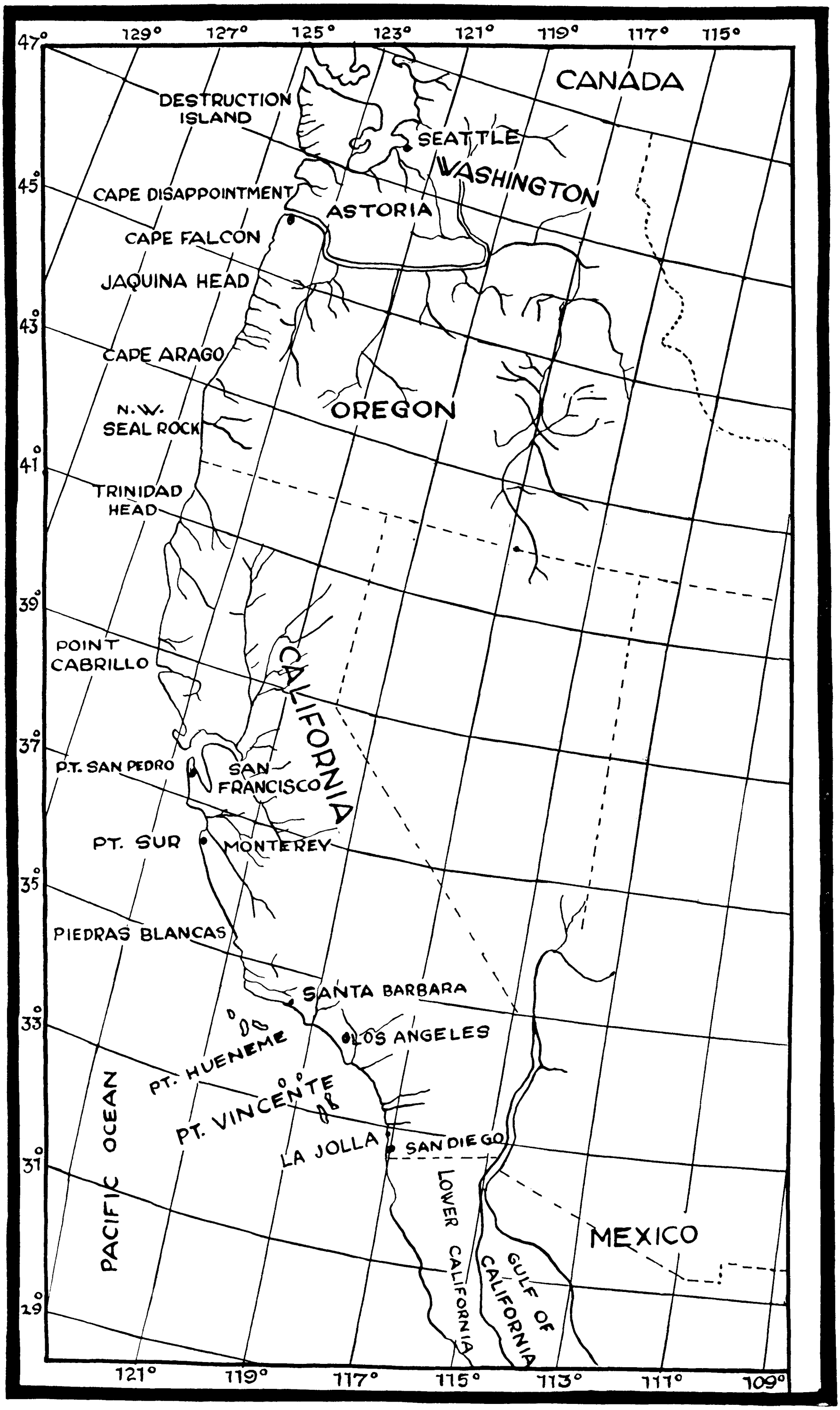

Fig. 1. Outline map of the Pacific Coast of United States, showing the location of the points mentioned in the text from which the catches were obtained.

of the species in the final record are capable of identification without much error. All of them were found in three or more of the areas mentioned.

In the Mortensen series only two genera, *Chaetoceras* and *Nitzschia,* were very prominent at any time, but in the McEwen series *Eucampia, Skeletonema,* and *Thalassiothrix,* though not reaching large numbers, were represented in sufficient quantity in some catches to deserve particular mention. This difference in the two series is partly explainable by the greater number and greater frequency of the catches by Dr. McEwen, but it is probably more distinctly due to the fact that most of Mr. Mortensen's catches were made in the poorly productive period of fall and early winter. A similar difference is discernible in the case of species of the genus *Chaetoceras,* for which only three forms reached notable prominence in one or more catches of the Mortensen series, while eleven forms reached considerable prominence in the McEwen series. But the records show that the prominence of these eleven species appears mostly in single catches which might very probably have been missed in the long and irregular intervals between Mr. Mortensen's hauls; hence, while greater frequency would adequately explain the prominence of *Chaetoceras* forms in the McEwen series, we know that the favorable season is mainly responsible.

Ten genera were listed in addition to those just named above, but no catch greater than 3,000 was taken of a single species in any genera at any point. The genera *Chaetoceras* and *Nitzschia* were the only ones which were represented by individual species in more than one fourth of the catches. In the McEwen series maximum catches of sixteen out of the thirty-three species listed were taken south of Cape Mendocino, which is near the northern border of the area I have designated as the Point Cabrillo region. This is the section in which there is greatest upwelling of colder waters and it is near the point at which the main body of the Japan current is carried well away from the shore. Hence it appears to be a natural point of division between southern and northern waters of our Pacific Coast line. Seventeen species yielded maximum catches north of Cape Mendocino. Furthermore, the maximum catches in both northern and southern directions were almost all distinctly larger than any catches of the same species which were taken respectively south or north of the cape. Five of the exceptions were to the south and one to the north. The latter has been found in pier collections as far south as Pt. Hueneme (see map, page 141), and it is quite probable that the other five might be found to the north if the number and continuity of catches was sufficient. From the limited evidence before us we can only conclude that so far as geographical range of species is concerned there is no very marked difference in the diatom flora throughout more than a thousand miles of Pacific coastal waters. As to quantity, the showing is somewhat different. Both the Mortensen and McEwen series show maximum catches of total diatoms in waters near or north of Cape Mendocino. Both series also showed a distinctly higher average of catches of diatoms in the northern section—*i.e.*, 56,056 as against 4,535 per liter in the Mortensen series and 139,294 as against 77,245 per liter in the McEwen series. In spite of the small amount of evidence furnished by two such short series as these, it seems fairly clear that the area north of Cape Mendocino is, on the whole, a much more productive area in a quantitative way. Since this conclusion agrees with conclusions reached by many observers in regard to other oceanic waters of northern latitudes, it may be regarded as certain that more northerly waters generally produce larger quantities of diatoms.

Less definite indication of greater productivity in northerly waters is given by the following points: In the Mortensen series 5 out of 30 catches north of Cape Mendocino exceeded 40,000 per liter, while to the southward only 2 out of 36 catches reached that number. In the McEwen series 16 out of 61 catches northward exceeded 40,000 and 10 out of 40 to the south exceeded it. Also the Mortensen series showed 9 out of 30 catches north and 9 out of 36 south to be in excess of 5,000 diatoms per liter; and the McEwen series showed 22 out of 61 catches north and 25 out of 40 south to be in excess of that number. From such records it would appear that the ratio of catches above a certain number is essentially the same in both regions, but that the northerly region has a larger percentage of catches which run far in excess of that number. Or we may say that it seems probable that when conditions in a locality are favorable to a certain degree of productivity the tendency is for northern localities to carry production much farther beyond that degree than is the case in southern localities. And, indeed, this is what we might expect from the generally accepted view that diatom production is favored by a certain proximity to land from which there is any considerable drainage. The vastly greater contributory drainage in northern waters on our Pacific coast should have some such enriching effect as is indicated by the above-mentioned differences in production in northern and southern sections.

Such records as we have available at the present time give little indication as to the influence of various physical and chemical factors involved on the questions of distribution in this series of collections. In the Mortensen series no catch yielding more than 5,000 cells per liter was taken in water of a temperature less than 54° F. or greater than 60° F. On the contrary, the largest catch (numerically) taken by Dr. McEwen was in water of the lowest temperature recorded in his series. This catch was made about ten miles south of Cape Mendocino and it consisted almost entirely of *Chaetoceras sociale* Lauder, characterized by very small cells very difficult to estimate (much less count), and a form rarely found in any collections made by our institution. However, the largest catches made in some other areas were taken from points showing lowest temperature for those regions at that time. Hence it seems likely that regions of upwelling water or influenced by drift of upwelling water may be exceptionally productive under some circumstances, and that a relatively wide range of temperature does not necessarily mean poor production. While we know that temperature is a most influential factor in all productive activity of living things, we are not able to say anything definite as to the mode or extent of its influence in diatom production.

In the Mortensen series only four areas seemed to be very productive. In order of numerical production these were Jaquina Head, Destruction Island, Pt. Cabrillo, and Pt. Hueneme. In the McEwen series they were Pt. Cabrillo, Destruction Island (including some catches inside the Straits east of Cape Flattery), Pt. Hueneme, Pt. San Pedro, Cape Disappointment, and Trinidad Head. In both series North West Seal Rock area seems to be very poorly productive and the McEwen series indicates the Jaquina Head region to be so, although it was most productive in the Mortensen series. Such facts serve to again emphasize the need of caution in stating conclusions about plankton production anywhere without long, continuous, and careful observations. As a matter of fact, the region of North West Seal Rock may be highly productive in certain years or certain seasons so far as we have any means of knowing at present.

Out of the innumerable questions always arising in connection with any study of marine life the following appear with especial prominence at this time, and for them we have no satisfactory answers:

1. Does productivity in deeper strata of the same waters vary in the same way as does that of the surfaces at the times of sampling or at any times? It probably does not, but we lack the complete evidence that it does not.

2. How is productivity at one place related to productivity at another? Did the highly productive areas in these series appear highly productive because certain plant foods were carried into them from others which by strong currents were thus kept non-productive, though contributing to productivity in other places?

3. Is high productivity in certain areas due to proximity of suitable breeding grounds for fish which produce the plant foods which in turn provide for their own feeding—*i.e.*, is it due to the fact that the organic cycle or circuit is completed in some areas, but not in others? There are vast numbers of minor questions leading from this.

4. If northern waters tend to be more productive, why did the Pt. Cabrillo and Jaquina Head areas show more fertility than the areas farther north in their respective series?

5. What was the extent of productivity in localities intermediate to those sampled at the time of sampling?

6. What was the extent of productivity at such times inshore, further off shore, and in deeper or shallower waters?

Fully satisfactory answers to such questions can be obtained only by colossal expenditures of time, money, and labor.

But in spite of the fact that so many highly important problems press vainly for solution it does appear that the study of this series of collections shows some points worth noting. These may be briefly stated as follows:

1. This evidence favors the generally accepted view that phytoplankton organisms are more abundant in northern waters.

2. It gives strong indication that certain areas are more productive than others, and that some may be highly productive at one time and poorly productive at another time within the productive season.

3. It shows decrease of production in all areas as winter approaches.

4. It shows that the region of prominent upwelling may be highly productive, at least at times, and that a temperature several degrees colder than that of adjoining waters does not prevent large production.

5. It indicates that our more prominent diatoms may exist or possibly flourish in surface waters of all areas sampled.

6. It suggests the probability that a limited series of collections of high frequency like those of Dr. McEwen may be almost invariably more valuable from the ecological standpoint than a discontinuous series carried over longer periods of time, but that the value of either or both may be very much increased by use of the other for comparison.

7. It shows that material obtained through use of commercial shipping may be highly valuable, and it indicates that there are important undeveloped possibilities of systematic work to be carried on through the use of commercial or naval vessels.